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## ABSTRACT

This report proposes a model for designing decision-making information systems in education. In the first section, several relevant themes in education and data processing are summarized, including user involvement, team effort, decision orientation, indicators, enabling technology, design methodologies, and process rather than product. The six steps in the design model are described in the next section: (1) needs assessment; (2) feasibility study; (3) conceptual design; (4) physical design; (5) implementation; and (6) evolution. The third section is a case study showing the application of the model to the design of a microcomputer database that would track referrals in the Portland (Oregon) Public Schools Alcohol and Drug Program. (27 references) (MES)

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THE Northwest Regional Educational Laboratory

# PROGRAM REPORT

## DESIGNING INFORMATION SYSTEMS IN EDUCATIONAL SETTINGS

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July 1988

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# **DESIGNING INFORMATION SYSTEMS IN EDUCATIONAL SETTINGS**

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**July 1988**

**Evaluation and Assessment Program**

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## Introduction

While business leaders have been using empirical data to aid decision-making, educators have been slow to follow suit. Within the last few years, however, the professional meetings and journals have shown increasing activity and interest in information systems. In part this is due to the emphasis on accountability in the school improvement movement. It is also due to a rising awareness of factors associated with data use. Since education is much more decentralized and service oriented than most businesses, the development of microcomputers and new classes of software has also contributed.

The kind of information system that is relevant here is not a clerical accounting or inventory system, though clerks may enter most of the data. Formal, structured methodologies exist for developing clerical systems but these are not very useful for a decision-oriented context (Vasta 1985). Instead, the system must be flexible and changing to meet evolving needs. The development process must focus on the appropriate data, how it will be used, and how it should be organized rather than detailed specification of the reports and other outputs of the system.

My purpose here is to propose a model for designing decision-oriented information systems in education. This is a process model, for my experience has been that a good design process will facilitate data use while a poor design process will guarantee failure. I will only briefly discuss implementation and utilization issues.

In developing this model, I have drawn heavily from the work of others in designing management information systems (MIS) and decision support systems (DSS) for business environments (Date 1983, Dickson 1968, Gast 1983, Vasta 1985). This literature is a rich resource but it is largely inaccessible and unfamiliar to educators. I have also drawn heavily from the work of other evaluators (Banks & Williams 1987, Cooley & Bickel 1986, Herman 1987). Evaluators are increasingly asked to play a new role, that of information system designer.

I have also drawn on my own experiences - and mistakes - building information systems in a range of contexts in education. In the last section I describe a case study where the proposed design model was applied. In that study, the director and advisory committee of a drug and alcohol program in a large school district contracted for the development of a system to track or monitor students referred to the program. My role in that project (Deck & Neill-Carlton 1985) was less as a third party program evaluator, but more as a technical assistant charged with implementing a system for the users so that they could monitor the program themselves.

## Lessons for Information System Designers

There are many good sources of literature to guide the efforts of the information system designer. Selected areas of study in both education and data processing are relevant. There are a number of important themes that can be found in one or more of these sources.

**User involvement.** Users include everyone from the data entry clerk to the highest level policy maker using reports from the system. First, the system must be consistent with their view of the world, otherwise they cannot use its output. Second, the users must feel ownership of and responsibility toward the system. Finally, the system must provide the right data in the right format at the right time to contribute to decisions the users must make. Without user involvement throughout the project, it will fail, as both the system analysis and evaluation utilization literature emphasize (Cooley & Bickel 1987, Gast 1983).

**Team effort.** Invariably, the information system is to serve users at several levels: teachers, administrators, board members, etc. Potential users at each level will have an important contribution and should be included on the development team. Many technical skills are also needed throughout the development process; some of these require an evaluation background and others require data processing experience. Evaluators can help identify indicators and suggest what analyses can answer the questions users pose. Data processing staff can help identify the appropriate technology to use, suggest design methods, and program the database.

**Decision orientation.** The starting point for the design effort must be to describe the context and uses of the information the system will provide. What day to day decisions are made? What are the current and anticipated policy issues? It is often difficult for users to articulate information needs but they can begin to describe what they do and what decisions they make. At the higher levels of decision making, it becomes increasingly difficult to anticipate which issues will be important in the future since they change so rapidly. The design considerations are quite different when the system is conceptualized in this way (Cole 1987, Cooley & Bickel 1986, Vasta 1985).

**Indicators.** Given a good description of the issues and decisions that must be made, specific indicators can be identified to describe the relevant inputs, processes, and outcomes of education. Selecting indicators can be a complex process as the current debate over national indicators suggests (e.g. Anderson 1987, Murnane 1987, Oakes 1987, Stearn & Hall 1987). From the utilization research and MIS literature we know that these indicators must be reasonable and understandable to the user, be reliable and valid, and be easy to collect. To put the results on an indicator in perspective, there must be comparative data over time and between groups.

**Enabling technology.** Great advances have been made in hardware and software over the last ten years that increase the utility of information systems. Microcomputers now have fast hard disks and sophisticated database and statistical software. Microcomputers and minicomputers, which are well suited to the decentralized structure of education, provide much more computing power for the dollar than before, and fit more easily in the budgets of educational institutions. Database and statistical packages, the so called fourth generation languages, reduce the development time of applications.

**Design methodologies.** There have been similar advances in design methodologies in recent years. As attention has shifted from clerical systems to management information systems to decision support systems, the methods used by system analysts have evolved from very structured approaches to a more interactive, flexible one (Dickson 1968). The development of the relational model has resulted in new database software that is easier to use and more flexible, and design principles to guide developers (Date 1983, Fink 1987).

**Process not product.** Such information systems cannot be packaged and exported to other districts (Cooley 1983). Even though another district might find many elements of the referral tracking system described in the case study useful, the design process is the key to build user commitment and to ensure that the system will yield information useful to the users. The literature on educational innovations suggests that there are process considerations at each stage of implementation.

## **A Design Model**

Table 1 outlines a design model appropriate for decision oriented information systems. The model is based on the methods applied in business settings. It works as well for state level information systems as for school level systems. The appropriate formality and scope of each step, of course, will depend on the scale of the information system that will be designed.

Table 1. A model process for database development.

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1. Needs assessment
    - a. Identify the primary users and other audiences
    - b. Identify the decision context for each user group
    - c. Identify the primary goals for the system
    - d. Select design committee
  2. Feasibility study
    - a. Assess climate for information system
    - b. Assess the appropriate indicators and analyses
    - c. Assess the appropriate computer technology
    - d. Make decision about proceeding
  3. Conceptual design
    - a. Build a model describing the application
    - b. Select appropriate indicators and analyses
    - c. Organize the indicators into a logical design
    - d. Conduct user reviews and revise design
  4. Physical design
    - a. Select the hardware and software
    - b. Develop the database program
    - c. Test the database with sample data and reports
  5. Implementation
    - a. Conduct a pilot study and revise database
    - b. Conduct user training in stages
    - c. Establish a technical support system for users
    - d. Establish user quality control procedures
  6. Evolution
    - a. Monitor the requests for information from the system
    - b. Expand or modify the system to meet new requests
-



## Needs Assessment

The needs assessment phase identifies the users and their general information needs. This phase should conclude with a clear statement of purpose and a design committee with broad user representation.

**Users.** Any information system that warrants such development effort suggested here will most certainly serve users at different levels. The primary users will enter data, make the queries, and benefit most from use of the data. There are other audiences, usually higher level decision-makers, that will receive information from the system but will not interact with the system directly.

**Decisions.** Users have great difficulty articulating their information needs. Creative strategies are needed to solicit questions from users; direct inquiries often result in silence because most users simply have not thought about information needs. It is helpful to have them describe what they do and focus on where decisions must be made. The design committee will then identify appropriate measures and later give the users a chance to react to them.

**Purposes.** Before embarking on a design effort, there must be an explicit, public statement of purpose that reflects the user groups and their needs: school level (e.g. Cole 1987, Cooley 1983) and state level (e.g. Cohen 1986, Kirst 1984) systems.

**Design committee.** The design committee should consist of representatives from the primary user groups. It should also have expertise in evaluation to help select indicators and analyses. Finally, it should have expertise in data processing. Not just any "computer expert" will have the required skills. To get the technical help needed, users should seek system analysts that have design experience and show concern for users and their information needs.

## Feasibility Study

The feasibility study should lead to a "thumbs up/thumbs down" decision about continuing with the design effort. Typical questions include:

- o Have the appropriate users and purposes been identified?
- o Is there strong user support for the system?
- o Can data be collected and analyzed to answer the kinds of questions users are asking?
- o Is there administrative and financial support for the system?
- o Is the information system technically feasible?
- o What is the correct technology to implement the system?

Note that the list includes human and resource questions as well as technical considerations.

Many information systems should not have been attempted in the first place. A feasibility study, even a rather informal one, can prevent wasted energy or head off disaster by pointing up weaknesses in the plan.

## Conceptual Design

The conceptual design phase of the information system is the most important and most time consuming part of the design process. Perhaps two thirds of the effort will be spent on the conceptual design. This is surprising to some because, traditionally, the physical design phase took so long. Here there is heavy involvement of users, with technical assistance from evaluators and system analysts.

**Descriptive model.** It is often helpful to help users develop a written or graphic description of the application (Fink 1987). The description will make explicit the knowledge users have about what happens to whom, when, and how outcomes are manifested. This process will require interviews or discussions with each user group. The model building process helps users articulate what really happens and ensures that the analyst fully understands the application before coding starts.

**Indicators.** The committee must identify indicators that capture key events (e.g. instruction) or important states at different points in time (e.g. achievement) based on the descriptive model. These indicators must be valid, reliable, and easy to collect. Data collection forms are a typical final product. This critical step will consume much of the time allotted for the conceptual design phase. The current debate over national indicators (e.g. Anderson 1987, Murnane 1987, Oakes 1987, Stearn & Hall 1987) may offer some help but more likely the specific decision context will suggest a relevant literature.

**Analyses.** Some sense of the analyses and data displays is also needed at this point. It is not necessary to design reports at this stage; a plan for the types of analyses and displays will be used. Comparisons between groups, profiles, trends over time, and graphs are among the many tools available. Perhaps sophisticated statistical analyses may be called for, but more often a simple list of students carefully selected on some criteria can have a major impact on users. This step may be more difficult and more critical in educational settings than in business, yet there is little documentation from previous efforts (Cooley & Bickel 1986, Deck 1987, Sirotnik & Burstein 1987) to help the designer develop useful displays that are technically sound.

**Logical design.** Given the descriptive model and the list of indicators, the analyst can formalize the logical design of the database. The MIS literature offers many approaches to implementing information systems, but the relational model is most relevant, since it results in a flexible database that is easy to change and to understand (e.g. Date 1984). Many of the more popular database programs are at least partial implementations of the relational model.

**User review.** The user review lets each user group see how their input contributed to the overall design and react to the design tradeoffs that were made. If there is much controversy or confusion, there should be an iterative sequence of reviews.

## Physical Design

Translating the logical design into a physical database system is largely a technical step that requires data processing skills. There should still be user involvement during this phase but it will likely be minimal. Certainly, the software tools available today minimize the time and programming skills required. With a good relational database

program, certain end users can develop rather sophisticated applications, but the majority of database users do little more than automate mail or phone lists. The tutorials for database software can teach users how to paint a screen and how to print a report, but the user has no opportunity learn relational design principles or how to avoid common design pitfalls.

The selection of hardware and software must occur simultaneously and be guided by the logical design of the database. The selection process must also consider institutional standards for hardware and software purchases, since the data processing department must be able to support users.

There is also no substitute for personal experience in designing databases. Traditionally, most district data processing staff have experience in clerical systems like financial and student accounting, rather than the more dynamic and user centered systems proposed here. Since a technical discussion of physical design issues is beyond the scope of this paper, little can be said about the steps of this phase.

While this phase requires technical skills users will not have, some continued, though infrequent interaction with the users, is still needed.

## **Implementation**

**Pilot study.** The test of the design process comes in the implementation. It is almost always the case that a pilot implementation with a subset of the data or at a small number of sites will bring a few problems to light.

**User training.** Obviously, training will be needed to teach users to enter data and print reports. Less obvious needs include training in the use of information generated by the system and training in creating new reports or database queries.

**Technical support.** Until software is very smart and computers are more like appliances, users will need technical support. Any problem that creates a bottleneck will cause frustration among users. Often a simple phone call or quick visit can solve the problem.

**Quality control.** When users care about an information system, they are usually very careful about the data entered. If something does not look right, they will make sure it is corrected. However, if the system is complex or if some of the data primarily serves someone other than the primary users, missing or inaccurate data can begin to accumulate and potentially erode the reputation of the system. Simple procedures can be instituted to catch bad data as early as possible with a feedback loop to make sure the problems are corrected.

## **Evolution**

Almost by definition, the kind of information system outlined here will change over time. The issues and decisions will change over time, especially the higher level policy issues. One sign of the health of an information system is that the answer to one question initiates new questions. New questions will require new reports and potentially new data collection. Some periodic or on-going mechanism for monitoring

should be planned for to monitor new requests and determine changes which should be made. Eventually, a redesign effort may be needed, but usually the changes are relatively minor if the original design was sound.

## A Case Study: Drug and Alcohol Referrals

Between the fall of 1985 and fall of 1986, NWREL staff were involved with a formative evaluation of the Alcohol and Drug Program for Portland Public Schools. During the planning for that evaluation, it became increasingly clear that a system to track students referred to the program was needed to answer many of the evaluation questions. Since the district wanted an information system that would continue to function after the contract was over, I was asked to examine the possibility of a microcomputer database that would track referrals over several years as part of the evaluation contract.

The cooperative effort that we undertook serves as a good case study of an application of the proposed design model. At this writing, the student database contains data on nearly three years of referrals and has seen much use from most of the intended users. This year the program director wrote an evaluation report for the school board using data from the system with little assistance from an evaluator. The database has proved quite adaptive as new questions have been posed.

### Needs Assessment

Once the Drug and Alcohol Program director decided that a database was necessary to track students, she contacted the data processing department which maintains a massive districtwide student database. The data processing staff estimated that they would not be able to start the project for over a year and suggested that it would not be appropriate to add that kind of data to the district database. It was clear that the work would have to be contracted. The program director, an evaluator, and a system analyst met to plan such an information system.

The program director, who had some background in evaluation, had clear notions about the primary users and the kinds of questions each thought were important. One reason was that the previous year she had introduced a paper system for collecting information about referrals and assessment. The limitations of those paper and pencil forms for aggregating data and even for tracking an individual student over time prompted much of her interest in using the computer. Another reason is that through many meetings with the program advisory committee and its evaluation subcommittee, many of the concerns of the various groups had already surfaced.

Our next task was to identify the primary and secondary users of the information system and infer their general uses of the information system. Our list included:

- o **Counselors** - This group is often responsible for referrals to the program. They work with the high-risk students through school support groups and family counseling. They need to know if students are attending the scheduled assessments, getting treatment or other services, and improving in school work.
- o **Secretary** - This person handles all the referrals, answers phone requests by counselors, and files the assessment or treatment reports from service providers. She needs to know whether students were still in school, transferred to another school, or still active. She needs to retrieve information quickly for any information kept on an individual student.

- o **Director** - The director coordinates with all agencies through the advisory committee and administers the program funds, activities, and policies. School staff provide the actual services to students. The director needs to monitor referrals, services, and progress.
- o **Advisory committee** - An interdisciplinary group with representation from treatment providers, health and human services agencies, and schools. They need to know how well the program is doing, where the program should be improved, and what kinds of students are falling through the cracks.
- o **Evaluation subcommittee** - These members of the advisory committee are charged with developing evaluation questions and interpreting the evidence provided by the information system and other sources.
- o **School board** - Board members are concerned with overall effectiveness of the program and with various specific policy issues such as "Do agencies making assessments only refer students for treatment at their own agency?"

**Design team.** The design team was easily determined: the program director would provide information about what happens to referred students and what kinds of information the various users were requesting, the evaluator would help select indicators and suggest analyses that would answer the list of questions that had already been compiled, and the analyst would guide the design process. The analyst, who was still having trouble understanding the subtleties of the student referral system, wanted to be sure that the conceptual design was very clear before proceeding. The program director, though quite aware of the interests of different users, wanted to ensure that each group had adequate input. All agreed that there should be a cycle of meetings with different user groups to verify their interest and information needs.

## Feasibility

Informally, the system analyst was conducting a feasibility study during the initial meetings. From the beginning, there was a strong sense of purpose from both the director and the advisory committee.

The project director also showed a strong sense of commitment to the database. She felt that it would help her both to manage the program and to set new directions. In addition, she demonstrated early on that she would be able to assemble the resources needed to implement the database - from providing staff time for data entry to dealing with district red tape. The importance of this leadership and commitment by the primary user of the database cannot be over-emphasized.

At this point, the analyst could estimate the scope of the system with simple "order of magnitude" calculations. We assumed that there would be about 500 new referrals added each year for a period of about 5 years with many students graduating or leaving the district. Given these assumptions, we would need less than 2 megabytes of storage over the life of the system. Thus, a hard disk based microcomputer could easily handle the amount of data to be processed.

The feasibility study was completed in just two meetings. All indications were that the database could and should be developed.



## Conceptual Design

Although the design team discussed the various services provided by the Alcohol and Drug program, they did not consciously try to start with an explicit model from the student's point of view. Rather, they focused on the list of questions and on the earlier paper system. As a consequence, it took some time for the analyst to develop an adequate understanding of the program.

As the design work continued, there were several meetings with the program secretary, the evaluation subcommittee, and counselors. Each group added a unique perspective.

The program secretary provided important revelations about how mobile this population of students was, and how difficult it was to keep track of a student over time. She was able to pull sample records showing the typical sequence of services following referrals. She was also able to suggest the data entry features and reports needed to handle the day to day program management.

The evaluation subcommittee had made a rather comprehensive list of issues; some to be answered with the database, others to be answered with surveys or other methods. This list included:

- o What are the characteristics of students referred to the program?
- o What are the primary reasons students are referred?
- o To what extent are different components of the Student Assistance Program used and by whom?
- o How effective is the program in preventing use, improving school performance, and reducing absenteeism?
- o How can the program be improved?

As a group, the counselors were surprisingly defensive. They were very concerned about confidentiality, especially that printed reports with student names might be left laying around. They did not immediately see the utility of the system for them. This was particularly disturbing since this was the only group that would see referred students regularly in the school and be able to report on their progress.

The basic descriptive model of the program with which the committee started was largely confirmed through this process. However, that initial model was over simplified and assumed that students proceeded through a rather linear sequence of services. Had the final design not been enriched through the various perspectives, the resulting database would have been much less useful and less accurate.

As the list of questions grew throughout the series of meetings, the design team struggled to select indicators that would reflect a key event or important student characteristic at one point in time without creating a data collection burden. Some indicators, like arrests and expulsions, were rejected, since it seemed unlikely that permission could be obtained to add them to the database. Perhaps the most interesting issue was how to assess whether these high risk students remained free of drug and alcohol abuse. The team decided to simply ask counselors to judge whether each student remained free and to also ask their confidence in that judgment.

The team also examined the list to decide what kinds of analyses and data displays would be required. They identified several kinds of analyses:

- o Management - student lists, quality control checks, and other reports that aid the day-to-day management of the database and ensure the integrity of the data
- o Student history - historical record for each student of assessments, treatment, progress reports, grades, etc. intended for the counselor
- o Profiles - summary of characteristics of selected groups of students (e.g. assessed students or support group participants)
- o Cohort summaries - summary of status for a cohort defined by year of referral and grade level
- o Gains - for a particular cohort, compare status at two points in time

During the latter stages of this phase, the analyst formalized the logical design by organizing indicators according to relational database design principles. He also met with data processing staff to determine how indicators like grades and attendance could be accessed from the district MIS system and imported to the database without reentering any data. The logical design was explicit about file organization and the coding of all data elements.

The design of the system summarized in table 2 was finally presented to the advisory committee for the last user review. Handouts included the data collection forms to show the data collected and sample reports to show what kinds of information would be available from the database.

Despite the fact that the design team had strong leadership from the program director and a paper system already operating, the logical design step took many months, much longer than expected. In retrospect, there were many reasons for the setback: it was difficult scheduling meetings, there were delays with administrative red tape, and other work interfered. The team and most of the users were satisfied with the design.



Table 2. Student Referral Database Contents.

Data File	Data Source	Contents
STUDENT	Referral Form Assessment Form District MIS	Referral information Drug usage at assessment Student demographics
ASSESSMENT	Assessment Form	Report from assessment agency
TREATMENT	Treatment Form	Report from treatment agency
PROGRESS	Progress Check Form	Judgments of drug use and progress Participation in support groups
MIS	District MIS download	Educational progress Participation in special programs
SCHOOL	State Education Directory	School information

## Physical Design

By this time, the team was confident that it had a good database design, one that captured key information about a student, but that required minimal data collection. The system analyst began work on the physical database design.

It was clear from the logical design that good relational database software was needed. After reviewing the type of data that would be stored, the kinds of reports that would be generated, and the features of the leading database products, the analyst selected DataEase. DataEase supports most of the features of the top relational database programs, yet uses a menuing system that novices find very helpful. The district data processing unit, however, had standardized on DataFlex, a program which was unfamiliar to the analyst and would be difficult for the program staff to use. The team met with data processing staff to explain the plan and get approval.

The next step was to select the appropriate microcomputer hardware. Although the program office owned an IBM PC and letter quality printer, it was clear that hard disk storage and a faster printer would be required. The analyst wrote hardware specifications, and the district data processing staff purchased equipment.

The choice of software proved to be a productivity enhancement. The analyst was able to paint seven data entry screens, design twenty report formats, write the draft documentation, and test the system with a limited number of cases in about one week's work. DataEase provided an excellent high-level development tool that eliminated the need for programming in the traditional sense of the word.

## Implementation

Late in the spring of 1986, the new data collection forms were distributed. The initial training on the database was held during the summer of 1986. Since school was not yet in session, it was possible to pilot the database using data collected on both the old and new forms during the 1985-86 school year. Both the conceptual and physical design proved sound, but many iterations were required for fine-tuning report formats and for adding new reports. These changes were usually made immediately onsite. By the beginning of the school year, the database was fully operational.

Later, additional training was provided on defining simple reports using the DataEase Query Language to answer unanticipated questions that might arise. Both the project director and secretary did learn to conduct queries, but they have not conducted as many of their own queries as expected. In a large part, this is because the typical question requires accessing three or more parts of the database simultaneously. For example, one such question was "What percent of the students referred between 7/01/85 and 6/30/86 who attended an assessment were drug free by the fourth quarter of 1986-87?" The users have found it more efficient and less frustrating to retain the analyst to periodically add new reports where the query was difficult.

After about a year and a half, the information system has functioned well. The program secretary and director make frequent use of the database. The director wrote an evaluation report using data from the system with little help from evaluators and presented it to the school board. There have been a few problems with the system, however.

- o Initially, few treatment reports were received from the treatment agencies. This situation was remedied through the advisory committee.
- o Counselors have made little use of the database, though this was not unexpected after the early meeting with this group. This year, up to three years of data will be available on some students and those data will be shared with the counselors.
- o These high-risk students have been more mobile and harder to track than anticipated. Despite the use of district MIS data to update the referral database three times a year, a large number of students are shown as active that cannot be found in the MIS. The director is currently trying to identify the reason why so many students are slipping through the cracks. There is some urgency to find a solution since the student lists sent to counselors will be inflated.

## Evolution

In the first year there were no longitudinal data on students, so users focused on management reports, student profiles, and comparison of certain indicators with district averages. Now that longitudinal data exists, there is real interest in evidence of change for various cohorts and selected groups. Although users had not articulated these specific questions during development, the design anticipated them. Many reports have been added to handle these requests. The users have developed some of their own queries and reports but, for the most part, the questions have been complicated enough to require assistance. An example is "What were the average GPA's

in the fourth quarter of 1986 and 1987 for students with assessment referrals between 7/01/85 and 6/30/86 (and for whom GPA was not missing for either quarter)?"

This year the district received a special grant under the Drug Free Schools and Communities Act to work with middle school students. The database will play a major role in the evaluation of services schools provide under that grant. It was very easy to add a field to the database to tag students participating in the grant without making any other changes to the database. That the change could be made on-site in a few minutes directly following the meeting underscores the kind of software support needed.

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